

Nurse-led non-ICU early rehabilitation after liver transplantation: a quasi-experimental study

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Abstract

Background

Enhanced recovery after liver transplantation depends heavily on coordinated nursing care, but early rehabilitation is commonly initiated after intensive care unit (ICU) stabilization. We evaluated a nurse-led pathway in which selected liver transplant recipients bypassed routine postoperative ICU transition and received protocolized early rehabilitation on the general ward.

Methods

This single-center quasi-experimental study compared 57 recipients treated after pathway implementation (January-June 2026) with 45 historical controls receiving conventional ICU-transition care (July-December 2025). Primary outcomes included recovery milestones, invasive-device retention, complications and multidrug-resistant organism (MDRO) infection. Secondary outcomes were length of stay and total hospitalization cost. Non-normally distributed outcomes were compared using Mann-Whitney U tests. Adjusted analyses used multivariable linear regression with HC3 robust standard errors.

Results

The intervention group had earlier feeding (median 13.0 vs 48.0 h), respiratory training (13.0 vs 48.0 h) and first out-of-bed activity (39.0 vs 72.0 h), and shorter urinary and central venous catheter retention (all $P < 0.001$ in unadjusted analyses). After adjustment for age, sex, body mass index, diagnosis, surgery duration and intraoperative blood loss, the pathway remained associated with earlier feeding, respiratory training and ambulation, shorter urinary and central venous catheter retention, and shorter length of stay. Total hospitalization cost was not significantly associated with the pathway after adjustment. MDRO infection was numerically lower (3.5% vs 13.3%), but the difference was not statistically significant (Fisher exact $P = 0.134$).

Conclusions

A nurse-led non-ICU transition pathway was associated with earlier achievement of key postoperative recovery milestones, reduced exposure to selected invasive devices and shorter hospital stay. Because the study used sequential historical controls, the findings should be interpreted as associations rather than causal effects. Prospective multicenter studies with contemporaneous controls are warranted.

Introduction

Liver transplantation is an established treatment for end-stage liver disease, and advances in surgical techniques, immunosuppression and perioperative care have shifted attention toward optimizing

postoperative recovery and long-term outcomes [1–4]. Despite these advances, liver transplantation remains a major surgical procedure associated with substantial physiological stress, postoperative complications, prolonged immobilization and high resource use [5, 6]. Enhanced recovery after surgery (ERAS) principles emphasize early nutrition, respiratory training, mobilization and timely removal of invasive devices, all of which depend on coordinated bedside nursing and may support functional recovery while reducing postoperative morbidity [7–9].

The traditional care model focuses on life support within the intensive care unit (ICU) but pays insufficient attention to the transition phase of early postoperative rehabilitation [10]. The traditional concept is that liver transplant patients should have early life support in the ICU and strict bed rest one week after surgery for early activities. It could prevent bleeding in the liver section and anastomosis in the transplant area due to early implantation activities [11]. However, sizeable surgical wounds, long bed braking time, and unstandardized and timely early activities will increase the incidence of complications, such as pulmonary infection, pleural effusion, pressure injury, lower limb venous thrombosis, which will lead to prolong the recovery time of liver transplant recipients and reduce their postoperative quality of life [12]. Therefore, optimizing perioperative management strategies and promoting rapid and safe rehabilitation of patients is of great significance for improving patient survival rates after liver transplantation [13]. Transplant center studies show improved postoperative monitoring and management can increase the one-year survival rate from 72% to 79% to 85% to 90% and the 10-year survival rate from 53% to 66% [14].

Early mobilization after transplantation is increasingly recognized as feasible and clinically important. Previous studies in critically ill and postoperative populations have shown that structured early activity can shorten recovery time and reduce complications related to immobility [10, 15–18]. In liver transplant recipients, intensive early rehabilitation in the ICU has also been evaluated, but most existing pathways remain embedded within an ICU-to-ward transition model [10]. This creates a potential tension between the need for close postoperative monitoring and the risks associated with delayed activity, extended catheterization, greater resource consumption and exposure to multidrug-resistant organisms [19–21].

Nurses are central to early postoperative recovery because they continuously assess physiologic stability, coordinate feeding and respiratory exercises, initiate and progress mobilization, manage invasive devices, monitor symptoms and identify deterioration requiring escalation of care. A structured nurse-led pathway may therefore provide a practical mechanism for translating ERAS principles into daily transplant care. However, evidence is limited regarding nurse-led pathways that allow appropriately selected liver transplant recipients to bypass routine ICU transition while maintaining access to rapid escalation when required. The nursing implications of such pathways - including protocolized assessment, early rehabilitation delivery, device management and discharge readiness - remain insufficiently evaluated.

Therefore, this study evaluated a nurse-led non-ICU transition early rehabilitation program developed from published evidence and multidisciplinary expert consultation. We compared early recovery

milestones, catheter retention, postoperative complications, multidrug-resistant bacterial infection, length of stay and total hospitalization costs between recipients treated after pathway implementation and historical controls receiving conventional ICU-transition care.

Methods

Study design and setting

This single-center quasi-experimental study compared two sequential perioperative care pathways for liver transplant recipients at a tertiary hospital in Chengdu, southwestern China. The control period was July to December 2025, when recipients routinely received postoperative life support in the ICU before transfer to the general ward. The intervention period was January to June 2026, after implementation of a nurse-led non-ICU transition early rehabilitation pathway in which selected recipients were transferred directly to the general ward after surgery. The study was registered in the Chinese Clinical Trial Registry (ChiCTR2500099945; registration date 1 April 2025), before enrollment in the reported control and intervention periods.

Participants

Eligible participants had end-stage liver disease, were scheduled for their first liver transplantation, agreed to participate, and provided informed consent. Exclusion criteria were repeat liver transplantation, cognitive impairment, limb paralysis, fracture, or severe cardiopulmonary insufficiency. The target sample size was calculated using $N = [(Z\alpha + Z\beta)^2 \times (2\sigma^2)] / \delta^2$, with $\alpha = 0.05$, $Z\alpha = 1.96$, $\beta = 0.10$, $Z\beta = 1.28$, $\sigma = 10.40$, and $\delta = 7.99$, yielding 35.57 participants per group. Allowing for approximately 10% attrition, the target was 40 participants per group. A total of 106 recipients entered the two periods, and 102 were represented in the final analytical dataset after four in-hospital deaths.

Development of the nurse-led non-ICU pathway

The intervention was developed from published evidence and guideline recommendations and refined through multidisciplinary expert consultation. Fourteen experts reviewed the draft protocol: four liver transplant physicians, six liver transplant nursing specialists (including three advanced practice nurses at organ transplant centers), two rehabilitation therapists, and two nutrition therapists. Experts were required to have more than 10 years of medical or nursing experience, more than 5 years of liver transplant experience, a master's degree or above, and an intermediate or higher professional title. Recommendations were incorporated into the final protocol, and nurses used a structured implementation checklist. The pathway included early postoperative feeding and nutritional support, respiratory function training, mobilization, rehabilitation exercises, and timely management of invasive catheters (Fig. 1).

Control condition

Recipients in the control period received routine postoperative treatment and nursing care. They were admitted to the ICU for early postoperative life support and subsequently transferred to the general ward, where routine rehabilitation and nursing care were provided.

Outcomes and data collection

Primary outcomes were time from surgery to first oral feeding, first respiratory function training, first out-of-bed activity, first flatus, and first defecation; retention time of the urinary catheter, central venous catheter, gastric tube, and arterial blood pressure catheter; postoperative complication burden; and multidrug-resistant bacterial infection. Secondary outcomes were hospital length of stay and total hospitalization cost. Baseline variables included age, sex, ethnicity, education, marital status, occupation, body mass index (BMI), primary diagnosis, surgery duration, and intraoperative blood loss. A trained investigator collected baseline, perioperative, and outcome data, and a second trained investigator reviewed the records. Data collection was stopped when a participant died during hospitalization. The analysis used the available participant-level dataset; no imputation was required for the analyzed outcomes in the updated dataset.

Statistical analysis

Statistical analyses were performed using Python 3.13, SciPy 1.17.0, pandas 2.2.3, and statsmodels 0.14.6. Continuous variables were summarized using medians and interquartile ranges (IQRs) when distributional assumptions were not met. Normality was assessed using the Shapiro-Wilk test and inspection of the observed distributions. Because most recovery, device-retention, length-of-stay, and cost variables were non-normal in at least one group, unadjusted between-group comparisons used two-sided Mann-Whitney U tests; rank-biserial correlation was reported as an effect-size measure. Categorical variables were compared using Pearson's chi-square test when appropriate. Fisher's exact test was used for sparse binary outcomes, with risk ratios (RRs) and 95% confidence intervals (CIs). Postoperative complication count was analyzed using the Mann-Whitney U test rather than a multi-category chi-square test.

Given the non-randomized historical-control design, adjusted analyses were performed for selected continuous outcomes using multivariable linear regression with HC3 heteroscedasticity-robust standard errors. Prespecified covariates were intervention group, age, sex, BMI, preoperative diagnosis, surgery duration, and log-transformed intraoperative blood loss. Variance inflation factors were examined to assess multicollinearity; all maximum VIFs were below 1.3. Residual heteroscedasticity and influential observations were examined, and log₁₀-transformed outcome models were used as sensitivity analyses for skewed variables. Statistical tests were two-sided and $P < 0.05$ was considered statistically significant. Because the binary infection and ICU-transfer outcomes contained few events, multivariable adjustment for these outcomes was not performed to avoid unstable overfitted estimates.

Results

Participant flow and baseline characteristics

A total of 106 liver transplant recipients entered the two study periods (59 during the intervention period and 47 during the control period). Two patients in each period died during hospitalization, leaving 102 recipients in the final analytical cohort (57 intervention and 45 control). The raw dataset contained limited item-level missingness, so outcome-specific denominators are reported where applicable. Measured baseline and perioperative characteristics were generally comparable between groups. Median surgery duration was 298 min (IQR 264–371) in the intervention group and 320 min (IQR 299–342) in controls ($P = 0.361$). Because of the non-randomized historical-control design, adjusted analyses nevertheless included prespecified clinically relevant covariates, including surgery duration and intraoperative blood loss (Table 1).

Table 1
Baseline characteristics of liver transplant recipients

Characteristic	Intervention (n = 57)	Control (n = 45)	P
Male sex, n (%)	48 (84.2)	30 (66.7)	0.066
Age, years, median (IQR)	53 (47–57)	52 (39–57)	0.395
Married, n (%)	53 (93.0)	41 (91.1)	0.941
Employed, n (%)	21 (36.8)	19 (42.2)	0.846
College/university or above, n (%)	21 (36.8)	16 (35.6)	0.739
Han ethnicity, n (%)	52 (91.2)	37 (82.2)	0.291
BMI, kg/m ² , median (IQR)	23.53 (22.32–25.82)	23.14 (20.96–25.88)	0.290
Decompensated cirrhosis, n (%)	33 (57.9)	23 (51.1)	0.409*
Hepatic failure, n (%)	7 (12.3)	10 (22.2)	
Hepatocellular carcinoma, n (%)	17 (29.8)	12 (26.7)	
Surgery duration, min, median (IQR)	298 (264–371)	320 (299–342)	0.361
Intraoperative blood loss, mL, median (IQR)	800 (600–1000)	1000 (600–1300)	0.554

Continuous variables were compared using Mann-Whitney U tests. Categorical variables were compared using Pearson's chi-square tests. *Overall P value for diagnosis distribution. IQR, interquartile range; BMI, body mass index.

Early rehabilitation outcomes

Distributional assessment showed that most postoperative timing variables were non-normally distributed in at least one group; therefore, primary unadjusted comparisons used Mann-Whitney U tests. Feeding, respiratory training, first out-of-bed activity, urinary catheter removal, and central venous catheter removal occurred earlier in the intervention group. Differences in time to first flatus, first defecation, gastric tube removal, and arterial catheter removal were not statistically significant under the distribution-appropriate non-parametric analysis (Table 2).

Table 2
Unadjusted early rehabilitation outcomes

Outcome	Intervention, median (IQR)	Control, median (IQR)	P	Rank-biserial r
First postoperative feeding, h	13.0 (10.0–15.0), n = 57	48.0 (27.0–72.0), n = 45	< 0.001	-0.853
First respiratory training, h	13.0 (11.0–15.5), n = 57	48.0 (45.0–72.0), n = 45	< 0.001	-0.873
First out-of-bed activity, h	39.0 (36.0–55.0), n = 57	72.0 (48.0–96.0), n = 45	< 0.001	-0.579
First flatus, h	57.5 (50.3–70.0)	48.0 (48.0–72.0)	0.134	0.173
First defecation, h	81.0 (68.0–105.5)	72.0 (48.0–96.0)	0.207	0.146
Urinary catheter retention, h	16.0 (14.0–24.0)	96.0 (54.5–120.0)	< 0.001	-0.887
Central venous catheter retention, h	22.5 (17.0–38.0)	72.0 (48.0–120.0)	< 0.001	-0.820
Gastric tube retention, h	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.156	-0.114
ABP catheter retention, h	22.5 (9.3–37.0)	34.5 (0.0–96.0)	0.250	-0.131

P values are from two-sided Mann-Whitney U tests. Negative rank-biserial values indicate lower values in the intervention group. ABP, arterial blood pressure; IQR, interquartile range.

Postoperative complications and multidrug-resistant bacterial infection

The median number of recorded postoperative complications was 1 (IQR 1–2) in the intervention group and 2 (IQR 1–3) in the control group ($P = 0.283$). Unplanned ICU transfer occurred in 2 of 57 intervention recipients (3.5%) and 2 of 45 controls (4.4%; Fisher's exact $P = 1.000$). Multidrug-resistant bacterial infection occurred in 2 of 57 intervention recipients (3.5%) and 6 of 45 controls (13.3%). Although the point estimate favored the intervention pathway, the confidence interval was wide and crossed the null (risk ratio 0.26, 95% CI 0.06–1.24; Fisher's exact $P = 0.134$) (Table 3).

Table 3
Postoperative clinical outcomes

Outcome	Intervention	Control	Test	P	Effect estimate (95% CI)
Postoperative complication count	1 (1–2), n = 57	2 (1–3), n = 45	Mann-Whitney U	0.283	
Unplanned ICU transfer	2/57 (3.5%)	2/45 (4.4%)	Fisher exact	1.000	RR 0.79 (0.12–5.39)
Multidrug-resistant bacterial infection	2/57 (3.5%)	6/45 (13.3%)	Fisher exact	0.134	RR 0.26 (0.06–1.24)

RR compares intervention with control. Outcome-specific denominators reflect available data.

Length of stay and total hospitalization costs

Length of stay and total hospitalization cost were right-skewed. In unadjusted analyses, both were lower in the intervention group: median length of stay was 13 days (IQR 11–16) versus 17 days (IQR 14–23; $P < 0.001$), and median total hospitalization cost was RMB 400381.50 (IQR 390039.64–409537.43) versus RMB 432475.80 (IQR 376589.00–465566.86; $P = 0.016$) (Table 4).

Table 4
Unadjusted length of stay and total hospitalization costs

Outcome	Intervention, median (IQR)	Control, median (IQR)	P	Rank-biserial r
Length of stay, days	13.0 (11.0–16.0)	17.0 (14.0–23.0)	< 0.001	-0.453
Total hospitalization cost, RMB	400381.50 (390039.64–409537.43)	432475.80 (376589.00–465566.86)	0.016	-0.279

P values are from two-sided Mann-Whitney U tests. Negative rank-biserial values indicate lower values in the intervention group.

Adjusted analyses

Because the study used non-randomized sequential historical controls and several outcomes were heteroscedastic, multivariable linear models were fitted with HC3 heteroscedasticity-robust standard errors. Models adjusted for age, sex, body mass index, preoperative diagnosis, surgery duration, and log-transformed intraoperative blood loss. After adjustment, the intervention remained associated with earlier feeding, earlier respiratory training, earlier first out-of-bed activity, shorter urinary and central venous catheter retention, and shorter length of stay. The raw-scale model also suggested a difference in ABP catheter retention, but this association was not reproduced in the log1p sensitivity model and was therefore considered model-dependent. Gastric tube retention and total hospitalization cost were not statistically significant in the primary adjusted models. Maximum variance inflation factors were

below 1.3, indicating no problematic multicollinearity. Log1p-transformed sensitivity analyses supported the adjusted findings for feeding, respiratory training, ambulation, urinary catheter retention, central venous catheter retention, and length of stay (Table 5).

Table 5
Adjusted associations between the non-ICU pathway and selected outcomes

Outcome	N	Adjusted difference*	95% CI	P
First postoperative feeding, h	102	-51.76	-70.71 to -32.82	< 0.001
First respiratory training, h	102	-56.58	-83.66 to -29.50	< 0.001
First out-of-bed activity, h	102	-60.48	-103.24 to -17.72	0.006
Urinary catheter retention, h	102	-85.93	-114.11 to -57.75	< 0.001
Central venous catheter retention, h	102	-66.17	-89.70 to -42.63	< 0.001
Gastric tube retention, h	102	-31.82	-63.68 to 0.05	0.050
ABP catheter retention, h	102	-26.11	-43.00 to -9.21	0.002
Length of stay, days	102	-4.48	-8.23 to -0.73	0.019
Total hospitalization cost, RMB	102	-16153	-59685 to 27379	0.467

**Adjusted mean difference for intervention minus control from linear regression with HC3 robust standard errors. Models included age, sex, BMI, preoperative diagnosis, surgery duration and log-transformed intraoperative blood loss. Negative values indicate earlier/lower outcomes in the intervention group.*

Discussion

In this quasi-experimental historical-control study, the nurse-led non-ICU transition pathway was associated with substantially earlier feeding, respiratory training, and first out-of-bed activity, shorter urinary and central venous catheter retention, and shorter length of stay after adjustment for measured baseline and perioperative factors. Total hospitalization cost was lower in the unadjusted comparison but was not independently associated with the pathway after covariate adjustment. Measured baseline and perioperative characteristics, including surgery duration, were broadly comparable in the updated dataset.

The adjusted findings for feeding, respiratory training, and first ambulation are consistent with the operational logic of an ERAS-oriented pathway in which nursing staff can initiate protocolized rehabilitation activities earlier when routine ICU transition is avoided [7–10]. Earlier removal of urinary and central venous catheters also remained independently associated with the intervention period. Although the raw-scale model for ABP catheter retention reached statistical significance, the corresponding log-transformed sensitivity model did not, so that result should be interpreted as model-dependent rather than robust. Influence diagnostics also indicated that the ambulation model contained

an influential observation, although the log-transformed sensitivity model preserved the direction and statistical significance of the group effect. Overall, these findings support interpretation of the pathway as a bundled care process rather than evidence that any single component independently caused the observed changes.

With the increasing maturity and rapid development of liver transplantation technology in China, it has become a routine operation for the treatment of end-stage liver diseases, ranking second in the world, second only to the United States [22]. The success rate of liver transplantation can reach more than 95%, and the survival rate of patients after 1, 5 and 10 years in larger transplant centers can reach 90%, 80%, and 70% [23]. Early postoperative rehabilitation is crucial for liver transplant recipients. Previous studies have proposed that liver transplant recipients should get out early after surgery [24]. Professor Ding [25] noted that the starting time for early rehabilitation is within 48–72 hours of admission to the ICU. However, there is a lack of evidence on the general ward without ICU transition after liver transplantation. Due to the limitations of various factors, such as medical team staff, technology, and medical equipment, most liver transplant patients have to go through ICU life support before transferring to general wards for follow-up treatment [26]. During the ICU transition, patients need to stay in bed and have various catheters, and the risk of various infections will increase. The LOS and costs will also increase, which is not conducive to the early rehabilitation of patients [27]. The early out of bed time of the intervention group was more in line with the guidelines recommendations, namely, on the first day after surgery [28].

The intervention protocol implemented in this study can significantly shorten the time of first feeding, respiratory function training, and first ambulation. This has a positive impact on promoting early ambulation, reducing the incidence of pulmonary infection, and improving the nutritional status.

The raw data also altered the interpretation of infection and complication outcomes compared with the original unadjusted summary. Multidrug-resistant bacterial infection was numerically less frequent in the intervention group (3.5% vs 13.3%), but the number of events was small and Fisher's exact test was not statistically significant. Likewise, complication count did not differ significantly when analyzed as an ordinal/count outcome rather than as a sparse multi-category chi-square table. These results remain clinically relevant signals, but they should be considered hypothesis-generating rather than confirmatory.

Unadjusted length of stay and total hospitalization cost were both lower during the intervention period. After covariate adjustment, the association with shorter length of stay remained statistically significant in both the raw-scale HC3 model and the log1p sensitivity model, whereas total hospitalization cost remained non-significant. This pattern suggests that the pathway may have been associated with faster discharge readiness, but the historical-control design still prevents a causal interpretation because unmeasured secular changes in operative technique, staffing, infection prevention, postoperative monitoring, or discharge practice may have differed between July–December 2025 and January–June 2026. The present data therefore support a consistent association with shorter length of stay but do not establish an independent cost-saving effect.

Implications for nursing practice

The findings have direct implications for transplant nursing practice. A non-ICU pathway requires nurses to use explicit physiologic eligibility and escalation criteria, deliver early feeding and respiratory exercises, initiate and progress mobilization, coordinate timely removal of invasive devices, and maintain continuous surveillance for deterioration. The observed associations suggest that protocolized nursing can be an important operational driver of early recovery after liver transplantation. Implementation should therefore be supported by competency-based staff training, standardized checklists, interdisciplinary communication, and rapid access to critical care when clinical instability develops.

Strengths and limitations

This study has the following limitations. First, all participants come from one hospital, which may limit the generalizability of the results. In the future, it is also necessary to conduct multicenter trials in different regions and levels of medical conditions. Second, our study only collected relevant data during the hospitalization of liver transplant recipients. With long-term follow-up, more valuable information can be obtained, which is the study we will continue.

Conclusions

A nurse-led non-ICU transition early rehabilitation pathway after liver transplantation was associated with earlier feeding, respiratory training and ambulation, shorter urinary and central venous catheter retention, and shorter length of stay after adjustment for measured covariates. Total hospitalization cost and multidrug-resistant bacterial infection were not statistically significant independent effects. These findings support the potential role of protocolized nursing in accelerating selected recovery processes after liver transplantation, but the non-randomized historical-control design precludes causal inference. Prospective multicenter studies with contemporaneous controls, predefined safety criteria and evaluation of nursing workload and implementation fidelity are warranted before broad adoption.

Declarations

Ethics approval and consent to participate

The study was approved by the Biomedical Ethics Review Committee of West China Hospital, Sichuan University (2024 Review No. 439). All procedures involving human participants were conducted in accordance with the Declaration of Helsinki and relevant institutional guidelines and regulations. All participants provided written informed consent before participation.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

JX and XF-X contributed to conceptualization, data curation, formal analysis, investigation, project administration and drafting the manuscript. TZ contributed to project administration. GX and JY-Y contributed to conceptualization, resources, supervision and critical revision of the manuscript. All authors read and approved the final manuscript.

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Not applicable.

Data Availability

The datasets used and/or analysed during the current study are not publicly available because they contain potentially sensitive clinical information, but de-identified data are available from the corresponding author on reasonable request and subject to institutional approval and applicable participant privacy requirements.

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Figures

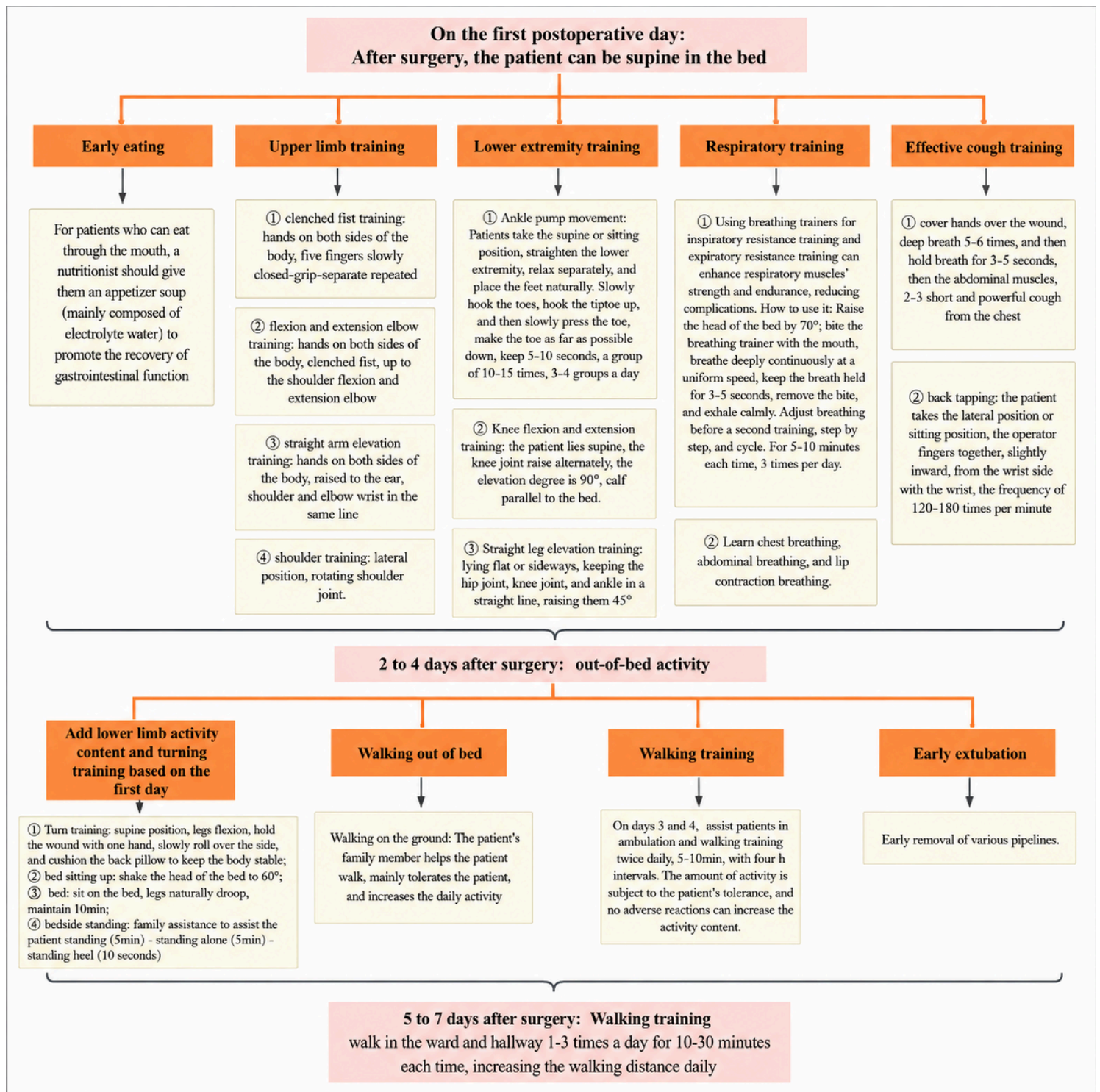


Figure 1

Nurse-led early rehabilitation program for non-ICU transition